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Baltic Earth 2.0
Science Plan 2025

The Science Plan provides the vision, structure, ongoing activities, and envisaged plans of a new phase of the Baltic Earth, henceforth called Baltic Earth 2.0

Introducing Baltic Earth 2.0

Vision

Baltic Earth 2.0 strives to advance Earth system understanding of the Baltic Sea region as the basis for science-based management under increasing climatic, environmental, and human pressures. Through collaborative research, workshops, conferences, and capacity-building activities such as training for early-career scientists, we strengthen scientific and human capacity in the region, while fulfilling our responsibility to synthesise knowledge and communicate it to stakeholders and research funders. Baltic Earth 2.0 addresses the atmosphere, land, and marine environments of the Baltic Sea and its drainage basin, in comparison to other analogue marginal sea regions worldwide.

Baltic Earth 2.0 is an open research network that welcomes both established and early-career scientists, as well as stakeholders. In contrast to its first phase, Baltic Earth 2.0 operates with a renewed organisational structure – including a new secretariat and revised science steering and senior advisory groups – and updated research topics, outlined briefly in this revised research plan. Further details on research themes and outreach activities are available on the webpages of the Baltic Earth Working Groups (www.baltic.earth/working_groups). As the science plan is a living document, the research topics will be updated regularly.

Baltic Earth 2.0 unites an international and interdisciplinary research community around core scientific questions essential for supporting society's efforts toward sustainability in the region. Participation in the network is entirely voluntary, with no research funding channelled to or through the network. Secretariat and administrative functions are provided by two leading research institutions: the Leibniz Institute for Baltic Sea Research Warnemünde (IOW, www.iow.de), Germany's leading research institute dedicated to the Baltic Sea ecosystem, and the Institute of Oceanology of the Polish Academy of Sciences (IOPAN, www.iopan.pl), a major centre for marine research in the Baltic Sea and polar regions.

Baltic Earth Study area

The Baltic Sea drainage basin covers about 16% of Europe, with roughly 85 million people living in the area. In the highly populated south, the temperate climate supports intensive agriculture and industry, while in the northern part, the landscape is predominantly boreal and rural. The semi-enclosed Baltic Sea has a complex bathymetry, strong horizontal and vertical salinity gradients, and extensive hypoxic and anoxic bottom areas.

It is characterised by a large freshwater supply from a catchment four times larger than the sea itself, long water-mass retention times, and an excess input of nutrients. With continued warming and associated changes in the hydrological cycle, shifts in temperature, salinity, and nutrient status are expected, with consequences for marine ecosystems and the services they provide to society.

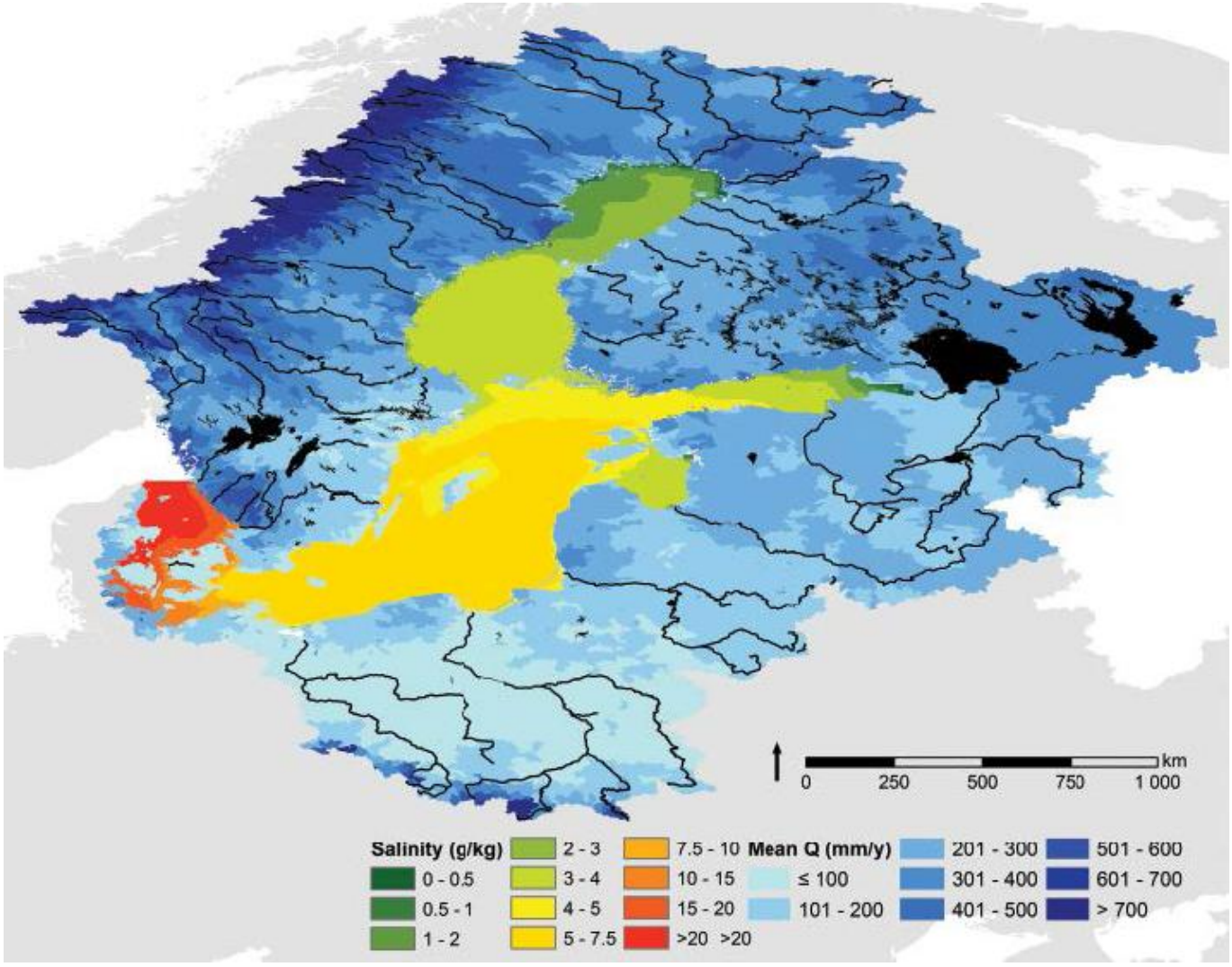

Figure 1 The Baltic Sea drainage basin together with the spatial variability in annual mean water discharge (Q) and sea surface salinity in the Baltic Sea. The salinity map shows the gradient from high (red) to low (green) salinities (from Meier et al., 2014; EOS Trans. Am. Geophys. Union 95(13), 109–110).

Climate change, along with other anthropogenic and natural changes in the atmosphere, on land, and in the sea, exerts multiple pressures on the natural and human-shaped environment of the region. These pressures include regional warming, declining sea-ice cover, sea-level rise, deoxygenation, acidification, altered precipitation and runoff patterns, and a changing frequency of high-impact events such as storm surges, floods, droughts, and heat waves. Characterising these pressures and synthesising scientific knowledge about their causes and impacts have been core goals of BALTEX (Baltic Sea Experiment, www.baltex-research.eu) and Baltic Earth Assessment Reports, BEARs (www.baltic.earth/projects/bear). It has been shown that observed environmental changes are often driven by a combination of interwoven factors – including climate

change and its associated impacts, eutrophication, pollution, fisheries, and land-cover change. Each of these factors has both scientific and societal dimensions, which are often interdependent, making it difficult to identify a single, or even dominant, driver of change.

Baltic Earth aims to analyse these factors and processes to identify knowledge gaps and research needs for the coming years, provide a scientific basis for management decisions and policymaking, and support efforts to address the challenges faced by society now and in the future. The Baltic Sea region is among the best-studied regions in the world from multiple disciplinary perspectives, with extensive data availability and many scientific and management aspects that offer analogues for comparison with other regions. In this sense, the Baltic Sea region may serve as a laboratory for understanding similar issues elsewhere.

Baltic Earth 2.0

Baltic Earth 2.0 aims to frame research on issues of fundamental importance for the science-based management of the Baltic Sea region's environment. It builds directly on the scientific foundations established during the programme's first phase, while responding to advances in Earth system science and to evolving societal and environmental challenges in the Baltic Sea region. In Baltic Earth 2.0, the former Grand Challenges framework has been replaced by a set of Research Topics in order to better reflect the maturity of the programme, the need for greater thematic clarity, and the increasingly interdisciplinary and solutions-oriented character of Baltic Earth activities. Several Research Topics continue and refine long-standing scientific priorities – such as climate variability, biogeochemical cycling, sea-level change, and natural hazards – that remain central to understanding the Baltic Sea system. Other topics have been restructured to better integrate processes across spatial and temporal scales and to address explicitly multiple, interacting drivers of change. In addition, new Research Topics have been introduced to capture emerging scientific directions, including future projections, human–environment interactions in marginal seas, and philosophical and conceptual aspects of Earth system research. Building on the tradition of scientific synthesis established during the BALTEX (Baltic Sea Experiment) and Baltic Earth programmes – through the BALTEX Assessment of Climate Change for the Baltic Sea Basin, BACC I (2008) and BACC II (2015), as well as the Baltic Earth Assessment Reports (BEARs) – Baltic Earth 2.0 catalyses a community-wide process to identify the most pressing scientific issues, knowledge gaps, and uncertainties. It promotes efforts to address these through new studies, collaboration, synthesis, and the development of tools. The BEARs, published in 2022, reflect both the BALTEX legacy and the transition towards new and emerging research topics, which will be continued and further expanded in the second phase of Baltic Earth. Publication of the next special issue of review articles, BEAR II, is planned for 2028/2029.

Nine revised or newly formulated research topics, each associated with a dedicated working group, will underpin Baltic Earth 2.0 activities in the coming years. Compared to the previous science plan from 2017, this science plan focuses on continuity. Research topics that have been thoroughly addressed and for which deliverables have successfully been submitted have been concluded. However, some topics are to be continued, and new

research topics have been added to address emerging challenges. Products of Baltic Earth 2.0 will include scientific assessments of specific topics, peer-reviewed scientific papers, and outreach publications for stakeholders and the public (such as the update of the HELCOM – Baltic Earth climate change fact sheet, www.helcom.fi/wp-content/uploads/2024/10/Baltic-Sea-Climate-Change-Fact-Sheet_2024.pdf), as well as research projects, workshops, seminars, and conferences. Baltic Earth 2.0 is also committed to capacity building and educational activities, including the continuation of regular Baltic Earth summer and winter schools for the next generation of scientists. The biennial Baltic Earth conferences have been very successful in providing a scientific platform for the exchange of research outcomes and ideas. They are a key forum for identifying new and updated research topics. Baltic Earth 2.0 will continue to collaborate with scientific communities around the world that share regional or thematic interests, such as the sub-programmes of the World Climate Research Programme (GEWEX, CORDEX and CLIVAR).

Research Topics

The Research Topics (RTs) are the central themes around which Baltic Earth science is organised. They reflect current issues regarded by the scientific community as highly relevant to the scope and vision of Baltic Earth 2.0. Over time, new RTs have been introduced and older ones discontinued as societal and research priorities shift and new issues of scientific importance emerge. Continuous review and possible revision of the RTs will take place through broad discussion within the Baltic Earth community, in conjunction with the biennial science conference, topical workshops, assessments, and other activities. Dedicated Working Groups (WGs) constitute the operational level for each RT.

The following section provides a brief overview of the current RTs addressed by Baltic Earth 2.0. The RTs replace the Grand Challenges of the previous Baltic Earth Science Plan published in 2017. The new suite of Baltic Earth RTs was developed following extensive discussions over the past two years and at the 5th Baltic Earth Conference in Jūrmala in 2024.

- RT1: Climate variability and teleconnections
- RT2: Small-scale (sub-mesoscale) processes and their impacts on large-scale Baltic Sea circulation
- RT3: Natural hazards and their impacts
- RT4: Sea level and coastal change
- RT5: Biogeochemistry of the Baltic Sea – Linking observations and modelling
- RT6: Multiple drivers of Earth system changes
- RT7: Marginal Seas – Humans and environment
- RT8: Future projections of the Baltic Sea region
- RT9: Philosophical aspects related to Baltic Sea Earth system research

In addition, a WG on Education organises summer and winter schools and other capacity-building activities.

Research Topic 1: **Climate variability and teleconnections**

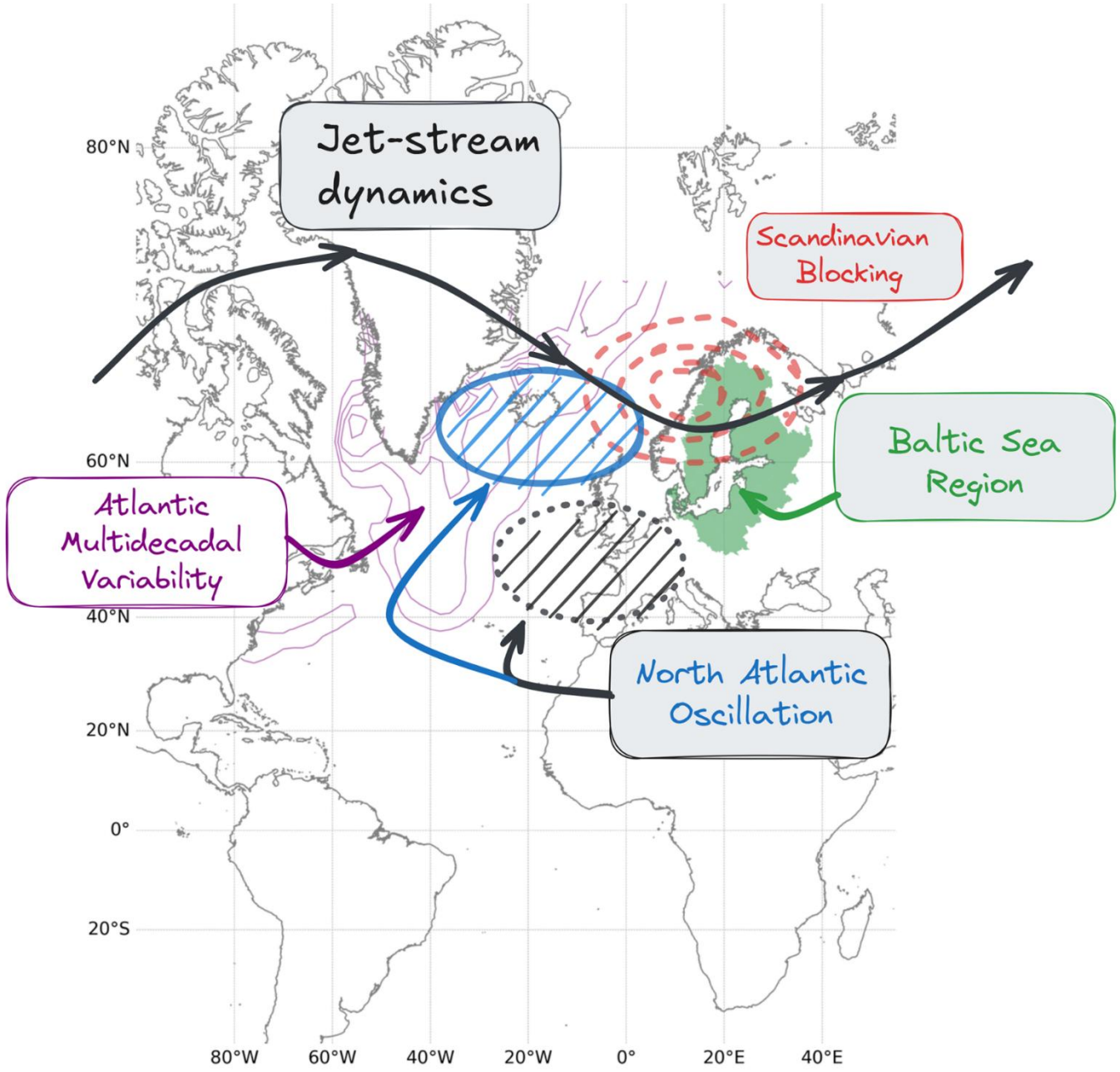

Figure 2 Baltic Sea catchment area (green) and schematic teleconnections influencing the climate of the Baltic Sea region: Atlantic Multidecadal Variability (purple), North Atlantic Oscillation (blue/black), and Scandinavian Blocking (red) (from Börgel et al., 2026; Earth Syst. Dyn. 17(3), 415–450).

Overarching research questions

- *How does large-scale climate variability, particularly from the North Atlantic, influence the climate of the Baltic Sea region across synoptic to multidecadal timescales?*
- *How will ongoing global warming modify key teleconnection patterns and their impacts on the Baltic Sea region?*
- *How can improved understanding of teleconnections enhance predictability of extreme events and regional climate projections?*

Background and objectives

Climate change manifests differently across regions, with some experiencing faster warming, altered precipitation regimes, or more frequent extreme events. Understanding regional impacts, and how these evolve under different socio-economic pathways, is therefore increasingly important. While large global model ensembles perform well for global-scale metrics, they often show substantial divergence at regional scales, even producing opposite signs of change for variables such as precipitation. This highlights the need for a focused assessment of regional climate variability and its drivers.

Previous BALTEX and Baltic Earth efforts have produced downscaled regional simulations for the Baltic Sea region, but a dedicated focus on how global climate variability connects to North European climate across different timescales has been lacking. Meanwhile, the number and quality of global and regional atmospheric reanalysis products have increased significantly, some extending back more than a century, enabling the study of low-frequency variability that was previously inaccessible.

Teleconnections from the North Atlantic strongly shape the climate of the Baltic Sea region. The North Atlantic Oscillation (NAO) influences winter temperatures, storm tracks, and precipitation patterns, while the Atlantic Meridional Overturning Circulation (AMOC) affects heat and salinity distributions. On shorter timescales, synoptic and intraseasonal variability driven by pressure systems and wind patterns produces pronounced seasonal and interannual variability. Understanding how these large-scale modes interact with regional atmospheric dynamics is essential for assessing climate variability and predicting extreme weather events.

Several important knowledge gaps remain. The detailed mechanisms linking North Atlantic variability to the Baltic Sea region, particularly on decadal and multidecadal timescales, are not fully understood; for example, the specific pathways through which changes in AMOC influence regional climate patterns remain unclear. The effects of climate change on established teleconnections are also uncertain, including how the frequency and intensity of modes such as the NAO and changes in jet-stream behaviour will evolve under future scenarios. In addition, the interactions between large-scale teleconnections and local climatic and oceanographic factors – such as land–sea contrasts, topography, and regional circulation – are not well documented. The role of teleconnections in modulating extreme events and compound events, where multiple factors combine

to produce severe outcomes, is another area requiring deeper investigation. Furthermore, the influence of teleconnection-driven physical variability, particularly regarding salinity, temperature, and nutrient cycles, on biogeochemical processes and marine ecosystems in the Baltic Sea is poorly understood. Finally, current climate models have limitations in simulating teleconnections and their regional impacts, underscoring the need for improved resolution and more advanced modelling strategies.

The overarching objectives of RT1 are to deepen understanding of the mechanisms linking global and North Atlantic climate variability to the Baltic Sea region; to determine how ongoing global warming is likely to alter these teleconnections across different timescales; and to enhance the capacity of regional climate models to simulate these interactions and their impacts. A further objective is to integrate physical, biogeochemical, and ecosystem perspectives in order to develop a more comprehensive basis for predicting climate variability, extreme events, and long-term changes affecting the Baltic Sea region.

Potential activities

Potential activities include assessing the quality of global simulations used for dynamic downscaling in the Baltic Sea region, and investigating global datasets such as ERA-20C or ERSST to identify energy and mass transports into the Baltic Sea catchment. Work will also focus on improving climate predictability and forecasts for Northern Europe by developing regional criteria linked to large-scale climate processes, including storm tracks, blocking events, and ocean–atmosphere interactions in the North Atlantic. Another important activity is examining how dynamically driven climate variability, such as jet-stream fluctuations originating far outside the region, propagates toward the Baltic Sea. Further efforts include identifying teleconnections between the North Atlantic and other critical remote regions and the Baltic Sea region across timescales from synoptic to decadal or centennial, and analysing how changes in atmospheric mass and energy flow over Europe under future climate conditions may affect the Baltic Sea and its catchment.

Research Topic 2: **Small-scale (sub-mesoscale) processes and their impacts on large-scale Baltic Sea circulation**

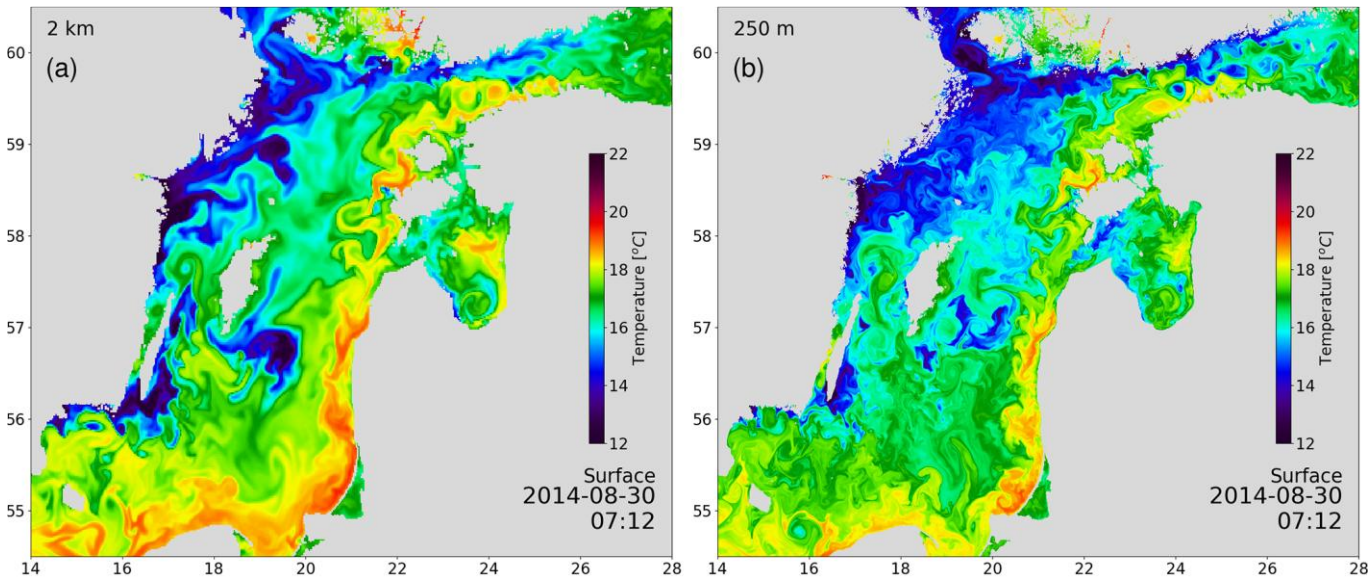

Figure 3 Snapshots of sea surface temperature (°C) from low-resolution (~2 km, left) and high-resolution (~250 m, right) simulations for the Baltic Sea. Mesoscale eddies are visible in both panels. However, the higher-resolution simulation (right) also reveals sub-mesoscale structures that substantially alter particle dispersion (from Gröger et al., 2022; Geosci. Model Dev. 15(22), 8613–8638).

Overarching research questions

- *How do sub-mesoscale processes influence vertical mixing, stratification, and coastal–offshore exchanges in the Baltic Sea?*
- *How is variability at sub-mesoscales connected to mesoscale and basin-scale processes, and how does this multi-scale interaction affect circulation, productivity, and biogeochemistry?*
- *Can models with sufficiently high spatial resolution accurately represent sub-mesoscale processes, and what measurements are required for a model-data comparison?*

Background and objectives

In the global ocean, the large-scale circulation and stratification are primarily driven by the fluxes of momentum, heat, and freshwater through the sea surface, along with their planetary-scale gradients. Similar processes govern the Baltic Sea system, where atmospheric forcing, heat and freshwater exchange across the sea surface, river input, and episodic inflow of saline water through the Danish straits shape the overall circulation. Energy introduced at large scales ultimately cascades toward progressively smaller scales, where it is dissipated at metre- to centimetre-scale turbulence.

The presence and importance of mesoscale eddies in transferring potential energy from sloping isopycnals into kinetic energy, and in mediating energy transfer from large to smaller scales, have been recognised for decades. However, the pathways through which energy flows from mesoscale to sub-mesoscale processes – and finally to dissipation – remain poorly understood. At the same time, numerous studies based on modelling, satellite remote sensing, and in-situ observations have documented the prevalence of sub-mesoscale features in the Baltic Sea. These features often occur in regions of strong horizontal buoyancy gradients, including coastal and offshore fronts, up- and downwelling, and along mesoscale eddies and frontal zones.

Observing sub-mesoscale processes remains challenging due to their small spatial scales (from 100 m to 2 km) and short temporal scales (from hours to days). Nevertheless, increasingly powerful modelling systems with sufficiently fine grid resolution, together with improved parameterisations and diverse experimental configurations, have greatly enhanced our ability to investigate the nature and large-scale effects of sub-mesoscale processes. Such models, however, require high-quality in-situ observations for validation.

RT2 aims to characterise sub-mesoscale variability and its connections to processes at other spatial and temporal scales – from basin-scale circulation and mesoscale dynamics to three-dimensional mixing and biogeochemical variability. Key topics include the influence of sub-mesoscale processes on vertical stratification, coastal–offshore exchanges, primary productivity, and air–sea exchange of climatically relevant substances such as greenhouse gases. These issues are crucial for understanding the broader impacts of small-scale variability on the Baltic Sea system. Emerging evidence suggests that inadequate representation of sub-mesoscale dynamics may be a significant source of uncertainty in ocean circulation simulations.

The main objective of RT2 is to summarise and synthesise current knowledge on sub-mesoscale dynamics and their large-scale impacts – including their role in the internal variability and predictability of the Baltic Sea system – and to outline priority research directions for the coming years.

Potential activities

Potential activities include providing an overview of the current state of knowledge on sub-mesoscale variability and its impacts on large-scale circulation patterns, including associated biogeochemical fields. Work may also involve identifying knowledge gaps and research needs, with the broader aim of improving the predictability

of the Baltic Sea system. Additional efforts may focus on compiling an inventory of relevant observational infrastructure, modelling platforms, and available datasets – including high-resolution monitoring programmes – within the Baltic Sea research community. Further activities may include suggesting topics, programmes, or project concepts to advance understanding of sub-mesoscale dynamics and their large-scale impacts, and identifying ways to implement the proposed actions, including mobilising the research community where appropriate.

Research Topic 3: **Natural hazards and their impacts**

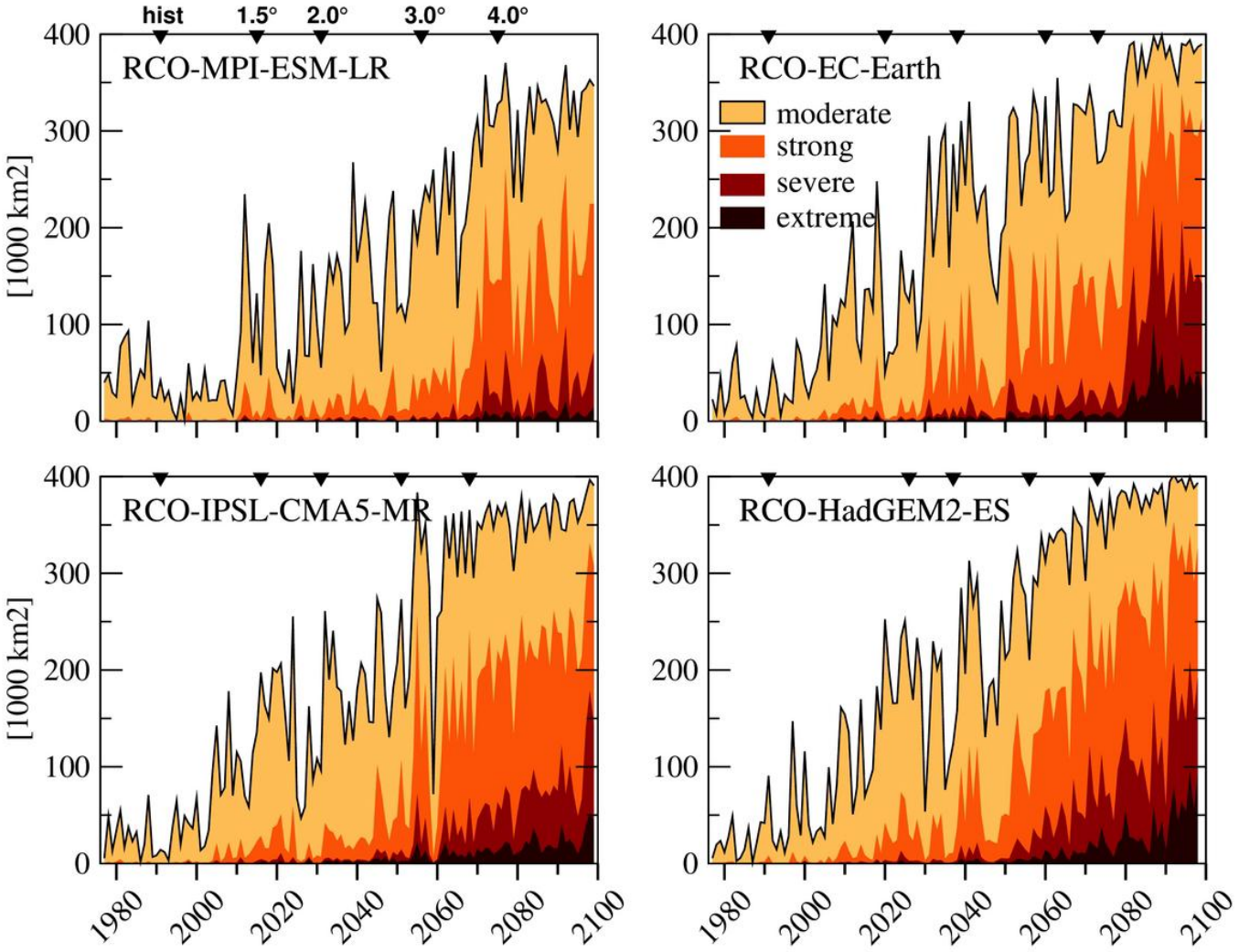

Figure 4 Annual mean sea surface extent of marine heat waves for the four models. Centers of 30-year historical and future periods, defined by global warming levels relative to the pre-industrial era, are indicated by triangles at the top of each panel. In all four models, the areas affected by annual average marine heatwaves increase significantly. By the end of the 21st century, heatwaves will, on average, cover almost the entire sea surface in three out of four models (from Gröger et al., 2024; Sci. Total Environ. 951, 175756).

Overarching research questions

- *How do natural hazards in the Baltic Sea region arise from the interplay of large-scale circulation, regional processes, and human-induced climate change?*
- *How can long-term data, counterfactual approaches, and reanalysis products improve attribution of extreme events and compound hazards?*
- *How will changes in natural hazards affect society, ecosystems, and key sectors in the Baltic Sea region in a warming climate?*

Background and objectives

Natural hazards are rare but impactful events that pose risks to human society and the environment. Their occurrence is shaped by a complex interplay of stochastic variability, natural climate processes, and human-induced drivers such as anthropogenic warming. Distinguishing the contributions of these different drivers is both scientifically challenging and essential for informed decision-making and raising public awareness. A major limitation in this context is the lack of sufficiently long observational records, which often do not capture the tails of probability distributions where extreme events occur.

Recent advances in atmospheric and oceanic reanalysis products, some extending back to the early 20th century, now make it possible to apply modern attribution techniques to Baltic Sea hazards. Counterfactual approaches – comparing real-world outcomes with hypothetical scenarios in which a specific factor such as anthropogenic climate change is absent – offer a promising way to quantify how the likelihood or intensity of extreme events have changed over time.

RT3 is closely linked to RT1 (teleconnections and large-scale circulation), RT4 (sea-level extremes and inundation), RT5 (biogeochemistry and harmful algal blooms), and RT8 (future projections). Together, these topics address hydrometeorological hazards such as storms, heavy rainfall, droughts, heat waves, high river flows, and compound events. While RT1 focuses on large-scale circulation patterns and their changes (e.g. shifts in storm tracks), RT3 examines how regional characteristics shape extreme events and determine their environmental and societal impacts. Because natural hazards directly affect life, infrastructure, and the human environment, socioeconomic expertise is essential.

Key knowledge gaps include limited understanding of how regional processes modulate large-scale drivers, how compound hazards interact, how natural variability and model biases affect projections of future extremes, and how these hazards translate into impacts on marine ecosystems and ecosystem services.

The objective of RT3 is to advance understanding of the drivers, characteristics, and impacts of natural hazards in the Baltic Sea region by integrating long-term observations, reanalysis products, and modern attribution methods. RT3 seeks to clarify how regional processes interact with large-scale circulation and anthropogenic

climate change to shape extreme and compound events. A further objective is to strengthen the capability to attribute past extremes and project future changes, including associated uncertainties. Ultimately, RT3 aims to provide a robust scientific basis for assessing societal and ecosystem impacts, thereby supporting climate-resilient risk management and adaptation strategies in the Baltic Sea region.

Potential activities

Potential activities include continued investigation of marine heat waves in the Baltic Sea, focusing on their occurrence, duration, extent, intensity, and underlying drivers. This includes analysing past trends in observational and reanalysis datasets and assessing how the specific characteristics of the Baltic Sea – such as its proximity to the Arctic, limited water exchange, and strong stratification – shape marine heat wave dynamics. Further work will explore how marine heat waves are likely to evolve under future climate conditions, and how uncertainties arising from natural variability and model biases influence projections.

Research will also investigate the ecological impacts of future marine heatwaves, informed by past events. Since temperature extremes affect dissolved oxygen levels (e.g. episodic hypoxia) as well as ecosystem structure and functioning, studies will consider interactions with other drivers such as eutrophication, sea-ice decline, and changing wind and wave climates.

A similar framework – covering occurrence, duration, extent, intensity, drivers, and impacts – will be applied to other natural hazards, including storms, heavy precipitation, droughts, high river flows, and heatwaves on land, as well as compound events involving multiple interacting extremes.

Research Topic 4: **Sea level and coastal change**

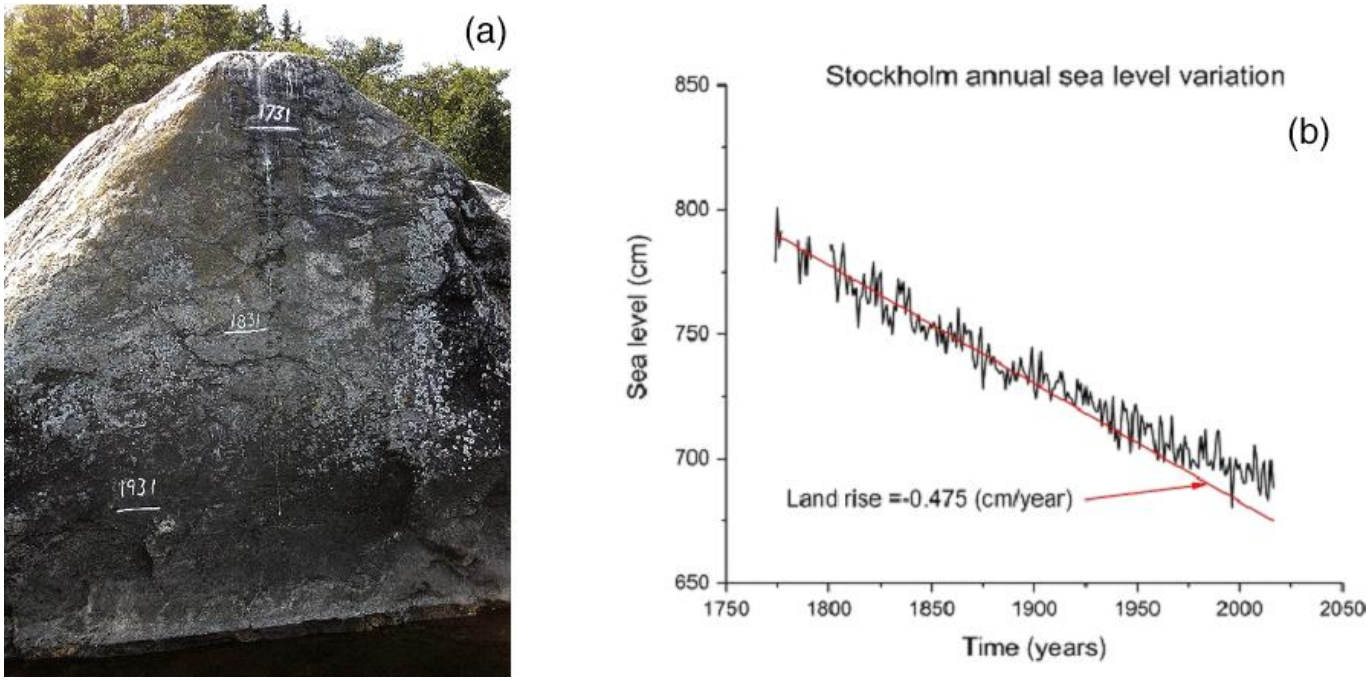

Figure 5 (a) The Celsius seal rock at Lövgrunden outside the Swedish city of Gävle on the Bothnian Sea coast. The present-day water level is about 2 m below the 1731 mark (photo courtesy of Martin Ekman). (b) Stockholm annual sea level variations (black) and land rise (red). Both panels illustrate glacial isostatic adjustment which is particularly large in the northern Baltic Sea (from Weisse et al., 2021; Earth Syst. Dyn. 12(3), 871–898).

Overarching research questions

- *How do evolving sea level trends and extreme coastal events, driven by e.g. vertical land motion, atmospheric forcing, and sea-ice dynamics, affect coastal flooding and erosion across the diverse geomorphological settings of the Baltic Sea?*
- *What is the role of changing wind patterns, wave climate, and sediment transport processes in driving short- and long-term coastal morphological changes, and how can predictive models be improved to capture these dynamics at fine spatial scales?*

- *How can long-term observational records, remote sensing, advanced modelling techniques, as well as AI/machine learning be integrated to deliver high-resolution, actionable predictions and projections of sea level and coastal hazards for use in adaptation planning at local, regional, and basin-wide scales?*

Background and objectives

Sea level varies at a range of scales, from a few hours to millennia. When considered in combination with weather-related drivers (winds, waves, river runoff, sea-ice cover) and on a backdrop of diverse coastal geology and geomorphology, coastal change varies spatially, often over short distances, and over time, sometimes in dramatic and unexpected ways. The Baltic Sea has some of the longest and best observed sea level records in the world. Together with satellite data and numerical modelling, this allows for high-resolution analysis of absolute (geocentric) sea level evolution in the context of global sea level change. At the shoreline, where change such as coastal erosion is experienced, relative sea level is influenced by land uplift or subsidence, so that much of the rocky northern coast is experiencing sea level fall while the southern sand-dominated coast is experiencing quite rapid sea level rise in line with global trends, leading to distinct coastal change that evolves over time.

Coastal change and (compound) coastal flooding are most obvious during storms when the sea level is elevated, the combined result of higher water levels that are driven by the dynamics of the North Sea, and processes driven by regional and local weather conditions against the backdrop of mean sea level rise. Because waves experienced at the shoreline are driven by local winds rather than by oceanic swell, wind direction is of the utmost importance, and climate change related long-term changes to wind, or winds from an unusual direction during a particular storm, can have very significant impacts. Communities along the coast have an urgent need for improved short-term prediction and climate projections of extreme sea levels and of waves at fine spatial scales applicable to small coastal segments and compartments, that are sensitive to shifts in wind directions and intensities. These analyses should also include the impact of seiches, meteotsunamis, the risk of compound flooding from rivers and sea, and changes to the duration and extent of sea ice cover. Less frequently considered, high waves coinciding with low water levels may impact the stability of the nearshore and navigation safety.

Coastal change is the result of waves and other coastal drivers mobilizing and transporting sediments. In situ data, essential for the estimation of actual sediment fluxes, is required for incorporation in improved sediment transport and coastal morphological models. Major progress towards the prediction of future coastal changes requires the integration of modelling, measurements and monitoring.

Potential activities

Because drastic coastal change and coastal flooding almost always occur during periods when elevated sea levels coincide with storms, the prediction of the nature and extent of sea level extremes is essential. At longer time scales this requires researchers to refine sea level predictions at a basin scale including improving our

understanding of links between the Baltic Sea and the North Sea. The input of climatologists, particularly concerning changing wind patterns (especially direction) is essential, for coastal scientists to be able to accurately predict extreme (both high and low) sea levels and wave conditions for small sedimentary segments and compartments. The Baltic Earth working group will have an important role in integrating the work of modellers, statisticians, climatologists and field scientists, utilising new data sources such as the Surface Water and Ocean Topography (SWOT) satellite and methods such as machine learning, as well as bringing together diverse data sets held in different jurisdictions. The working group will provide robust advice to hazard researchers, coastal managers, engineers and the wider community, applicable at the local community as well as at regional and basin-wide scales.

Research Topic 5: **Biogeochemistry of the Baltic Sea – Linking observations and modelling**

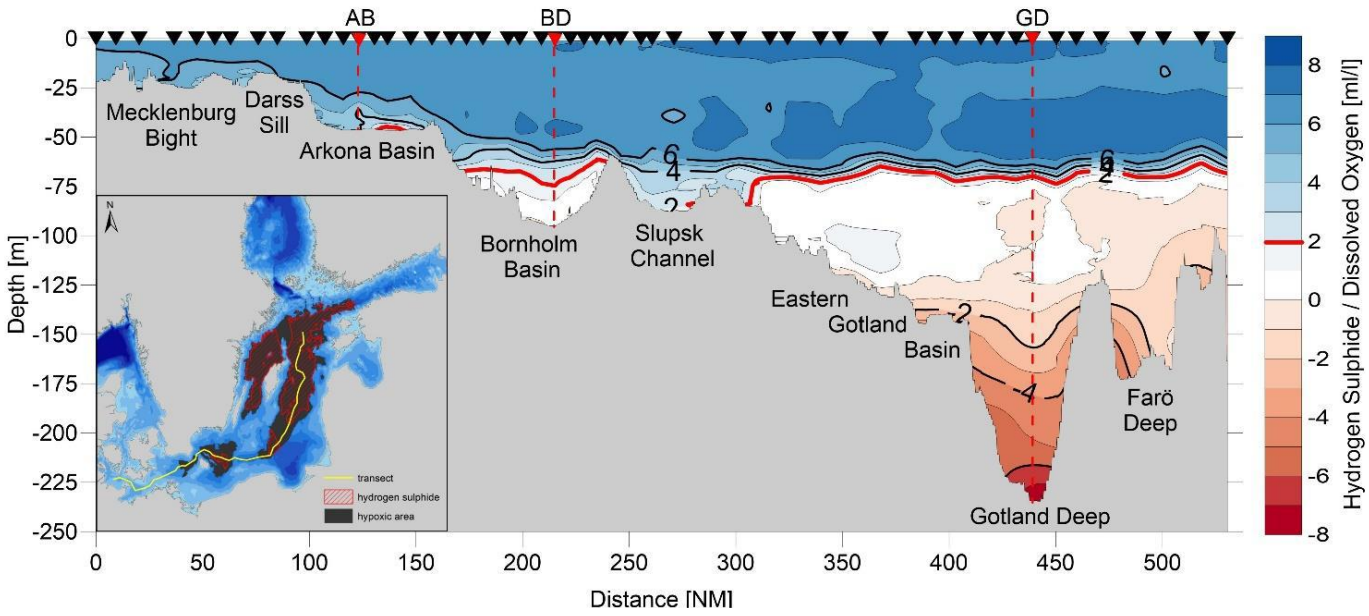

Figure 6 Transect from the Great Belt to the central Baltic, showing the recent state of dissolved oxygen and hydrogen sulphide (converted to negative oxygen equivalents) concentrations along the pathway of saltwater inflows from the western Baltic Sea to the deep basins (July 2020, IOW). Locations of CTD measurements and water sampling are marked by black triangles along the track. Red triangles mark the positions of the key stations Arkona Basin (AB), Bornholm Deep (BD) and Gotland Deep (GD) a. The map (left lower corner) shows the position of the transect (yellow line) and the hypoxic and euxinic area (dark grey and red hatch) (from Kulinski et al., 2022; Earth Syst. Dyn. 13(1), 633–685).

Overarching research questions

- *How do physical, chemical, and biological processes interact to regulate the biogeochemistry of the Baltic Sea across spatial and temporal scales?*
- *How can observational and modelling approaches be integrated to better quantify and predict biogeochemical cycles under changing climate and nutrient-load scenarios?*

- *Which environmental drivers and feedbacks control key processes such as oxygen consumption, remineralisation, and organic matter burial?*

Background and objectives

The Baltic Sea is a complex and highly heterogeneous ecosystem shaped by its unique hydrographic setting, including large riverine freshwater input, rare intrusions of saline water from the North Sea, and persistent vertical stratification. These features, combined with historically high external nutrient loads – peaking between 1975 and 2000 – have led to widespread eutrophication. The combination of both water column stratification and eutrophication resulted in the expansion of the hypoxic and anoxic areas in the central Baltic, starting already in the 1950s–1960s. This has caused redox alterations in the nutrient cycles promoting denitrification and increasing phosphorus recycling or reducing its burial efficiency. On top of that, there is also an influence of ongoing climate change, exemplified in temperature increase, which in the Baltic Sea region is higher than the global mean, and in changes in the precipitation patterns.

Although the major biogeochemical processes driving the elemental cycles of carbon, nitrogen, phosphorus, and oxygen are well established at a conceptual level, the detailed interactions among environmental forcing, biological communities, and physical dynamics remain insufficiently understood. Furthermore, the occurrence of strong biogeochemical gradients, both vertical, from air-sea interface through the stratified water column to sediments, and horizontal, along the land-ocean continuum, makes deciphering the role of individual biogeochemical processes even more challenging and requires the application of multiple drivers approach in research. Quantification of the regulatory effects that salinity, temperature, light, availability of oxygen, concentrations of nutrients and trace elements (including pollutants), biological community composition, and food web dynamics have on rates of important biogeochemical processes is fundamental for properly calibrating coupled hydrodynamic–biogeochemical models, which are the only tools to track the large-scale changes in the ecosystem and predict its future development under various climate and nutrient input scenarios. This can be done only by integrating and harmonising numerical studies with observations, as synergistic activities from both fields may significantly enhance the capacity to close existing knowledge gaps.

Several important knowledge gaps remain. A clearer understanding is needed of how C:N:P stoichiometry evolves during spring and summer blooms and how this variability influences broader ecosystem functioning. Oxygen dynamics in deep-water layers also remain insufficiently quantified, including the magnitude of sinks and sources and the drivers controlling the expansion and contraction of hypoxic and anoxic zones. The processes underlying the decoupling between alkalinity and salinity – and its implications for ocean acidification – are still poorly constrained. The role of dissolved organic matter, particularly terrigenous inputs, in nutrient cycling and its transformation within the Baltic Sea is also not well understood. Furthermore, the spatiotemporal variability of organic-matter remineralisation and burial in sediments requires deeper investigation, including the extent to which these processes are shaped by changes in microbial communities

and benthic fauna. Finally, interactions between contaminants and biogeochemical processes, including the combined effects of contaminant mixtures, remain largely unexplored.

Potential activities

Addressing existing knowledge gaps requires efforts beyond the capabilities of individual research groups, scientific disciplines, or research projects. Therefore, collaborative activities are needed to coordinate the enlargement and harmonization of data sets and improve the parameterization of biogeochemical processes. Achieving these goals can be facilitated by regular communication of needs and opportunities in both directions between modelers and experimentalists to build and continuously update a research strategy. This does not only concern the traditionally understood field of marine biogeochemistry but requires pursuing a more holistic approach, combining representatives of various scientific disciplines. This ambitious vision is the basis of the Baltic Earth working group, which will become an interdisciplinary platform enabling an efficient combination of numerical research and observations aimed at better understanding the biogeochemical functioning of the Baltic Sea across different spatial and temporal scales.

Research Topic 6: **Multiple drivers of Earth system changes**

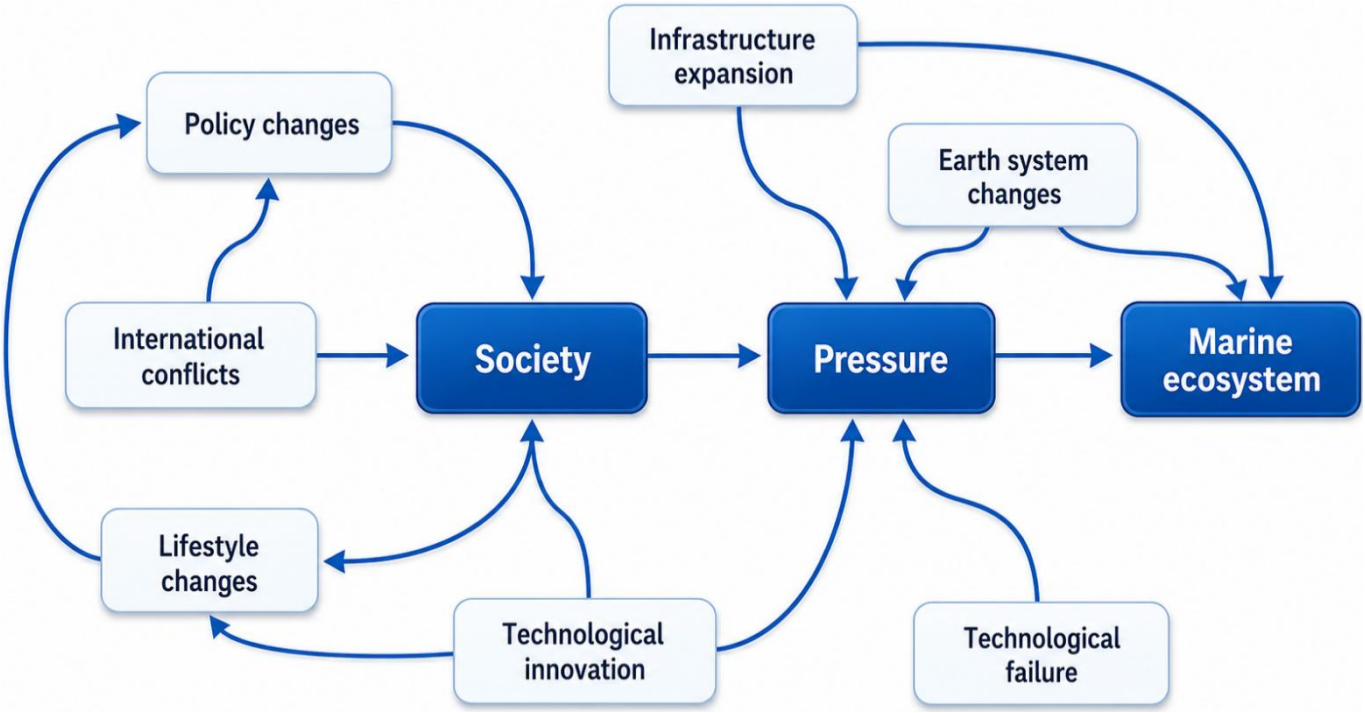

Figure 7 Representation of the direct and indirect pathways of impacts on the marine ecosystem. Wild card or low-probability, high impact events may cause unexpected changes in the society causing changes in drivers and pressures that directly impact the marine ecosystem. This is not an exhaustive list of potential pathways or impacts.

Overarching research questions

- *How can societies improve preparedness for low-probability, high-impact wild-card events, and to what extent can modelling tools assess their ecological and social consequences and provide decision support for risk management and adaptation?*
- *What is the readiness of the Baltic Sea for developing Digital Twin Ocean applications, and their potential added value for ecosystem management?*

Background and objectives

The Industrial Revolution, along with subsequent technological advancements, economic growth, urbanization, and globalization, has dramatically transformed the world. These developments have brought immense benefits to humanity but have also led to harmful and detrimental impacts on ecosystems. Despite numerous national and international policies and legislation aimed at controlling pollution, overfishing, and biodiversity loss, many aquatic and terrestrial ecosystems remain in poor condition. Identifying effective management strategies is still hindered by our incomplete understanding of the complex interactions between different drivers and impacts.

The overall aim of the group is to increase our understanding on the multiple interactions between the human and natural systems that drive pollution, overuse and degradation of aquatic environments, with a specific focus on the Baltic Sea and its catchment area. Building on earlier Baltic Earth projects and contributions, RT6 adopts a forward-looking perspective that introduces holistic systems thinking to support more reliable forecasting and better-informed decision-making. The group concentrates on drivers, interactions, and historical developments that contribute to the current environmental challenges in the Baltic Sea region. It addresses key knowledge gaps that limit effective environmental management. The work contributes to the further development of coupled models that are used to predict how marine, terrestrial, and atmospheric systems may respond to future trends, hazards, or policy interventions, thereby strengthening the scientific basis for sustainable management of the Baltic Sea environment.

Potential activities

The working group under RT6 organises meetings and workshops to facilitate collaboration, exchange knowledge, and inspire new research directions. Current activities centre on two main themes. The first examines whether existing tools and approaches are adequate for anticipating and managing future environmental hazards in marine and coastal environments. The second explores the potential of Digital Twin Ocean concepts for the Baltic Sea, evaluating current readiness, identifying gaps, and assessing the expected benefits for modelling, forecasting, and ecosystem-based management.

Research Topic 7: **Marginal Seas – Humans and environment**

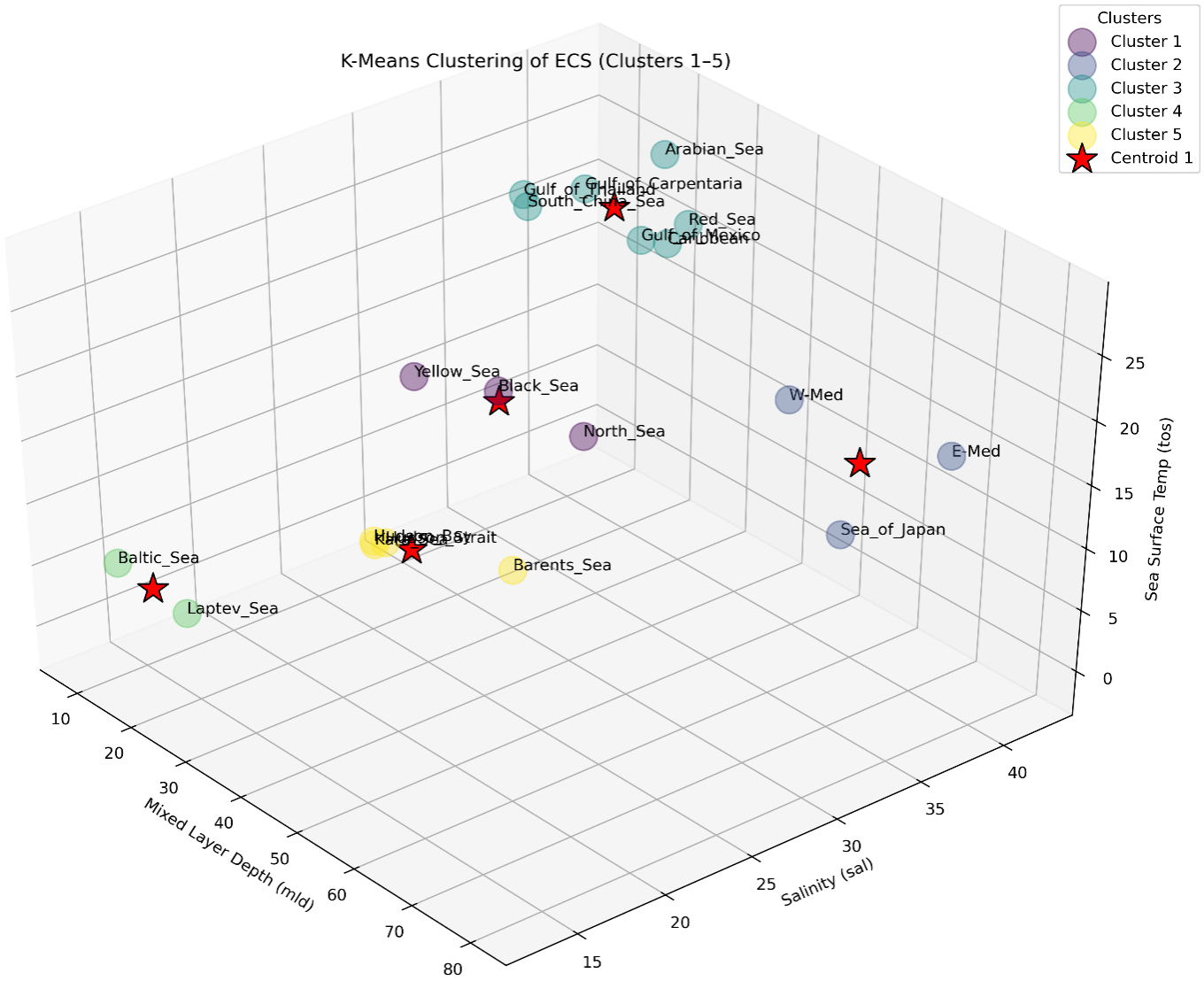

Figure 8 Algorithmic clustering of 19 marginal seas according to ecosystem relevant parameters. Coloured circles indicate the position of individual seas in the parameter space (mixed layer, salinity, sea surface temperature). Red stars indicate the position of the 5 cluster centroids. In order to compare the Baltic Sea with other coastal seas, this study sought to identify typical clusters across a number of coastal seas. (from Gröger et al. 2026; Commun. Earth Environ. 7, 312).

Overarching research questions

- *How does the Baltic Sea differ from other marginal seas, or which marginal seas are similar to the Baltic Sea?*
- *What are the regional peculiarities of the relationships between drivers in Earth systems with regard to marginal seas, and which of these relationships are invariant with respect to their regional assignment and indicate analogies?*
- *How can identifying analogies of drivers in marginal seas' Earth systems help to optimize sustainable development concepts?*

Background and objectives

Marginal seas are highly sensitive regions of the world's oceans, equally exposed to the pressures of climate change and increasing anthropogenic impacts through the overexploitation of natural resources. These pressures lead to the progressive deterioration of fragile marine ecosystems and necessitate complex management strategies for their protection and the sustainable use of valuable marine resources. This requirement not only presents regional challenges – such as those faced by the Baltic region – but is increasingly taking on a global dimension. A significant challenge in this context is the persistent gap between society's demand for effective management strategies and the scientific understanding of the cause–effect relationships linking environmental drivers to key ecosystem parameters in marginal seas. Bridging this gap requires not only solutions tailored to individual seas but also efforts to generalize across their diversity, thereby supporting the development of standardized and transferable concepts for sustainable management. For a generalized sustainable development of marginal seas in line with the UN Sustainable Development Goals (SDGs), a comparison with the Key Messages of the latest IOC Ocean Report 2024 is a useful tool when seeking analogies.

Historical datasets and accumulated scientific knowledge provide an important basis for comparing marginal seas worldwide and for developing a taxonomic framework that enables such generalisation. RT7 aims to contribute to this emerging taxonomy by examining the interplay of climatic, geological, ecological, and socioeconomic systems as drivers of environmental change. The spatial framework is set by the shelf seas, their coastal zones and drainage areas. The time frame is determined by the last glacial cycle, but especially the postglacial time – the period of human-nature interaction. Data sources to be considered range from local and regional monitoring programmes – including, where available, high-frequency or real-time observations – to global satellite-based observations. Long-term trends in human–nature relationships will be reconstructed using proxy data from natural archives interpreted through transfer functions. Numerical functional models and emerging machine-learning approaches provide powerful tools for evaluating and integrating these datasets.

Potential activities

Potential activities within RT7 include organising workshops, topical sessions at scientific conferences, and targeted publications to facilitate discussion of scientific results and to communicate findings to the broader public. To achieve its scientific objectives, the working group will collaborate closely with other Baltic Earth working groups and maintain active links with scientific organisations and institutions beyond the Baltic region. During the first phase, a joint publication (white paper) is planned as a review article outlining the current state of marginal seas research and future directions, with the aim of initiating a broad discussion on a general concept for the sustainable development of marginal seas ("upscaling of knowledge"). The working group also aims to collaborate with scientists from overseas to promote global comparative studies of marginal seas

Research Topic 8: **Future projections of the Baltic Sea region**

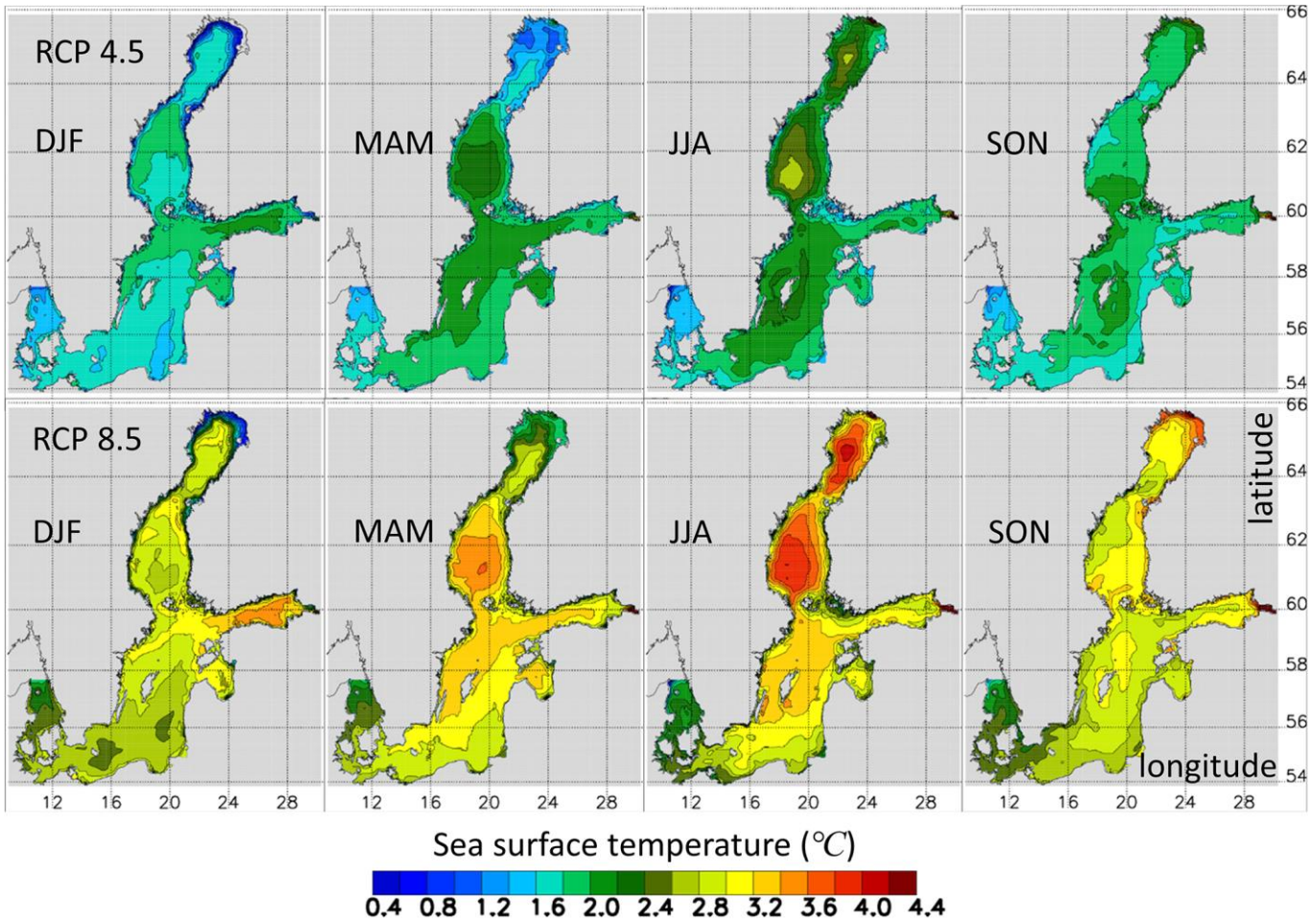

Figure 9 Changes in seasonal mean sea surface temperature (SST) as simulated by an ensemble of 48 scenario simulations. From left to right, mean SST changes (in ºC) in winter (December, January and February; DJF), spring (March, April and May; MAM), summer (June, July and August; JJA) and autumn (September, October and November; SON) between 1976–2005 and 2069–2098 under RCP4.5 (upper panels) and RCP8.5 (lower panels). The annual mean SST in RCP8.5, averaged over the sea surface, is projected to increase by 3.2°C by the end of this century (from Meier et al., 2021; Commun. Earth Environ. 2, 50).

Overarching research questions

- *How will the climate of the Baltic Sea region change in future and what are the causes?*
- *What climate data are needed by society and how can the continuous need for climate data for climate adaptation be met, taking into account the uncertainties due to model shortcomings, future greenhouse gas as well as aerosol emissions, land-use changes, nutrient loads and natural variability?*

Background and objectives

In Baltic Earth, regional Earth system models for the Baltic Sea region consisting of compartments for the atmosphere, ocean, sea ice, land surface and the terrestrial and marine ecosystem have been developed in the past, but also today, and used to downscale available projections of future climate, e.g. from CMIP5. Global climate models are still too coarse to reflect the details of the Baltic Sea region (orography, land-sea mask and relevant regional processes). Hence, the increased horizontal resolution and better process descriptions, e.g. mixing in the ocean, by regional climate models are needed. The added value of the latter was proven by many studies. Because projections of future climate are needed for climate adaptation, regular updates of scenario simulations are required, following the CMIP protocol. While the production of regional projections for the atmosphere and data provision are internationally coordinated within CORDEX, there is not yet a comparable project for regional oceans, especially for coastal seas such as the Baltic Sea. In cooperation with a number of recently approved national and international (EU) projects, the existing regional climate models will be used to create new scenario simulations for the Baltic Sea region under CMIP6 and CMIP7 and in upcoming phases, internationally coordinated by CORDEX and CLIVAR. A key objective of RT8 is to advance the development and evaluation of high-resolution regional Earth system models and to generate large multi-model ensemble simulations that allow for more robust quantification of uncertainties.

Potential activities

Potential activities under RT8 include performing multi-model ensemble scenario simulations using regional coupled Earth system models (RESMs) with the highest available horizontal and vertical resolutions, driven by the latest CMIP data and following international standards coordinated by CORDEX and CLIVAR, including common simulation protocols and standardised datasets. Work will also focus on calibrating new generations of RESMs to reduce model uncertainties, as well as evaluating climate models over the historical period to identify robust biases and the underlying processes that require improvement. Natural variability will be assessed through large ensemble simulations, complemented by the development of model substitutes (emulators) using machine-learning methods to expand ensemble size with reduced computational resources. Further activities include exploring the predictive capacity of regional and global climate model simulations with the aim of producing decadal climate predictions for the Baltic Sea region, and contributing to the international community of regional climate modellers and model users by supporting knowledge exchange across model domains. The research topic will also support climate-impact and adaptation needs by engaging with relevant

users and stakeholders, such as HELCOM, and by providing data and expertise to climate services, including contributions to the Baltic Earth–HELCOM Climate Change Fact Sheet. Finally, the RT8 will contribute to expert assessment reports, including BEAR II and IPCC AR7.

Research Topic 9: **Philosophical aspects related to Baltic Sea Earth system research**

Figure 10 On the link between natural sciences and art (Photo: Sabine Billerbeck).

Overarching research questions

- *Why should the BALTEX/Baltic Earth programme be considered of importance?*
- *How should complex environmental problems be approached and addressed?*
- *What core message should be communicated to society?*

Background and objectives

The Baltic Earth Working Group on Philosophical Views of the Baltic Earth and Science was established as a forum for reflecting on the conceptual, methodological, and societal dimensions of Baltic Sea Earth system research. Over three decades, the BALTEX and Baltic Earth programmes have significantly advanced scientific understanding of climate and environmental processes in the Baltic Sea basin and have made substantial efforts to communicate this knowledge across disciplines and to the public. Building on this experience, RT9 aims to explore the deeper philosophical questions that accompany the continuation and future development of the programme.

Central themes include the methodological foundations of Earth system science, such as the philosophical basis for caring about the ocean and its marginal seas, the limitations of dichotomous thinking, and the need for integrative perspectives. The RT9 considers the tension between traditional reductionist and mechanistic scientific approaches and more holistic or interaction-based frameworks, and reflects on the balance between general claims and context-specific insights in complex systems with multiple drivers. Questions about models, methodologies, metrics, and statistics are examined alongside the broader issue of how social dynamics and societal values influence scientific modelling. A second thematic focus concerns the philosophical interpretation of the BALTEX/Baltic Earth programme itself: its aims, unique characteristics, scientific challenges, and public relevance. Particular attention is given to how the programme's impact can be understood and assessed within the landscape of international Earth system research initiatives, and to the messages it conveys to society about environmental change and responsibility. A third area addresses the nature of good science and its role in society. This includes reflections on how scientific knowledge contributes to human well-being, the basis for public trust in science, the nature of the knowledge landscape in the Baltic Sea region, and the boundaries between scientific inquiry and activism. Together, these discussions aim to deepen understanding of how scientific evidence, societal needs, and philosophical perspectives intersect and shape the future of Earth system research.

Potential activities

Planned activities include regular meetings and discussions within the working group, the preparation of scientific publications, and the BALTEX/Baltic Earth book about basic ideas behind Baltic Sea Earth system research aimed at making the programme’s research accessible to the next generation of students and scientists. Through these activities, RT9 seeks to foster an open dialogue on the philosophical foundations of Baltic Earth research and to strengthen its societal relevance and long-term orientation.

Working Group on Education

Figure 11 Participants of the 11th Baltic Earth Summer School on “Climate of the Baltic Sea Region”, held on 18–25 August 2025 at Askö, Sweden (Photo: Eva Lindell).

Overarching research questions

- *How to teach knowledge about the Earth system and research on mitigation and adaptation of climate change and other drivers of Earth system changes in the best possible way?*
- *How can the range of Baltic Earth courses for students and early-career scientists (ECSs) be improved?*
- *How can advanced ECSs be trained and involved as tutors for Baltic Earth courses, so that they themselves can go on to become teachers and professors?*

Background and objectives

The aim of Baltic Earth is to train a new generation of Earth system scientists for the Baltic Sea region and for the global Earth system who conduct interdisciplinary and holistic research in the context of Baltic Earth. As this training is not offered at most universities in Baltic Sea countries, Baltic Earth offers courses for masters and doctoral students in order to build on existing knowledge.

The courses aim to convey the theoretical foundations of the Earth system functioning. In addition, application-oriented research is taught in order to find solutions for climate, environmental and other societally relevant problems. In particular, basic and advanced knowledge about the climate system consisting of the atmosphere, the ocean, sea ice and the land surface as well as the terrestrial and marine ecosystems is taught. The role of other human influences on the Earth system and a comparison with other coastal seas is also being intensively analysed and discussed. The courses teach the basics of dynamic Earth system modelling, the development and application of modern observation methods and the use of statistical methods to analyse observation data and model simulations. In some courses, for the exercises and tutorials, introductions to programming are offered to the students. In addition to basic knowledge about the Earth system with its many processes, skills such as science communication, presentation techniques, literature surveys, and proposal writing are also taught.

Usually, lecturers from different disciplines and locations take part in the schools, providing a wide range of expertise. By regularly organising summer and winter schools and hybrid master's courses open to guest students from countries all around the Baltic Sea but also outside of Europe, Baltic Earth has succeeded in significantly increasing the number of ECSs attending Baltic Earth workshops and conferences.

Potential activities

The aim is to maintain the ambitious teaching programme of the past in the future. The series of summer and winter schools will continue. The annual summer school, primarily aimed at master’s students, focuses on the climate of the Baltic Sea region and is organised by Rostock University and the Leibniz Institute for Baltic Sea Research Warnemünde at the Askö Laboratory operated by the Stockholm University Baltic Sea Centre. The annual winter school, covering various topics and aimed at doctoral students and other ECSs, rotates between institutes in the Baltic Sea region that are responsible for the local organisation. The international Baltic Earth Secretariat supports the organisation and implementation of both schools. As in the past, additional courses on topics such as remote sensing, instrumentation of observing systems, regional and global Earth system modelling, ecosystem modelling, and related topics will be organised. When possible, regular courses at various universities in the Baltic Sea region are made available for remote participation in a hybrid format. It is also envisaged that additional practical exercises, field courses, and introductory training in programming and Earth system modelling will be added to the offerings.

Instruments and Planned Activities of Baltic Earth 2.0

Participating scientists contribute to Baltic Earth 2.0 by sharing their time, expertise and research findings with the Baltic Earth community. New results and findings of interest to Baltic Earth 2.0 and wider scientific and stakeholder communities, including the general public, shall be published on the Baltic Earth website, on social media and blogs, in the Baltic Earth Newsletter and Secretariat Publication Series, and as peer-reviewed research and review articles and assessment reports. Generally, contributing scientists are expected to conduct their Baltic Earth–related research and travel to meetings and conferences at their own expense, as there is no central budget for Baltic Earth. It is desirable that contributing scientists are active in applying for Baltic Earth–related research funding at national and international levels, to facilitate collaboration and joint research activities. Engagement by research institutions active in Baltic Earth–related scientific fields is strongly encouraged, as Baltic Earth is by definition a collaborative effort.

Assessments

Assessment reports summarizing the current state of knowledge in specific scientific fields are a central product of Baltic Earth. Following the BALTEX (2008) and Baltic Earth (2015, 2022) assessments on climate change and other natural and anthropogenic drivers of the Baltic Sea Earth system, assessment reports will continue to be multi-authored and will summarise consensual knowledge on specific topics. They will also identify areas where scientific understanding is uncertain, helping to highlight knowledge gaps that require further research. Assessments may take the form of textbooks (such as the BACC assessments), journal review papers or series of papers (such as the BEARs).

Networking activities

Networking activities are vital for maintaining an active and creative scientific community, providing an arena for scientific discussions around the Baltic Sea and for communicating findings within the network while continuously developing the research topics. Regular Baltic Earth conferences stimulate an active process of identifying new research topics and highlight activities involving stakeholders. In addition to the generally biennial Baltic Earth conferences, sessions with a Baltic Earth focus are organised at other conferences (e.g. BSSC and EGU). Conferences, workshops and seminars on specific topics are organised by the working groups to support research topic development. These activities are aligned with meetings of the Baltic Earth

Science Steering Group (BESSG), the Baltic Earth Senior Advisory Board (BESAB), other relevant meetings, or held as stand-alone events.

Capacity building

Educating and supporting ECSs is a core element of Baltic Earth. Regular one-week summer (since 2015) and winter (since 2021) schools provide focused training on topics relevant to the Baltic Sea region. The annual summer school at Askö, Sweden, attracts master's students, while the University of Rostock offers a complementary hybrid course on "Climate of the Earth System" during the winter term. These activities are open to graduate students and ECSs from the region and beyond.

Dedicated seminars, conference sessions and the Baltic Earth Colloquium – featuring lectures by internationally recognised scientists every other month – further support the integration of ECSs into the scientific community and foster exchange across career stages.

Text books

Baltic Earth 2.0 is also producing a text book for Masters and PhD students as well as early career researchers in essay style, introducing the Baltic Sea region Earth system. The book introduces the main ideas and research achievements that shaped our understanding of the Baltic Sea Basin Earth system and that have had an impact on research communities of regional Earth systems worldwide.

Data resources

Data relevant for Baltic Earth research cover a wide range of disciplines, data types, periods, geographical extent, frequency and spatial resolution. There is ongoing development of data bases and data centres covering a variety of disciplines partly or entirely of relevance to Baltic Earth science, maintained by other organisations e.g. WDCC, GRDC, ICOS, ICES, Copernicus, national weather and hydrological organisations. Baltic Earth will support and highlight existing resources (e.g. on the Baltic Earth website) to develop a meta-data centre with data sources relevant for the network and the research topics. In addition, there will be a continuous identification of new data needs for current and future research topics.

Models and Scenarios

The Baltic Sea and the surrounding region has been the target of numerous modelling studies led by Baltic Earth scientists, building on model development by climate and marine as well as atmospheric research centres as well as University-based groups in several of the Baltic Sea countries. Modelling capacity in the region includes atmospheric, marine oceanographic, marine ecosystem and biogeochemical, terrestrial ecosystem, carbon cycle, and agricultural and forest production modelling. Earth system models coupling the atmospheric, marine and terrestrial components are hosted by national climate centres and research institutes in several

countries. Frontiers in regional Earth system modelling include the integration of linkages and feedbacks across components such as the role of land-sea nutrient fluxes for marine ecosystem dynamics and sea surface-atmosphere greenhouse gas exchange.

Models are useful for process studies, but also for the production and elaboration of scenarios of potential future changes and policy impacts. Scenario simulations are not predictions, but provide a framework for analysis and discussion of future changes in the context of specific assumptions and trends. They thus provide an important tool for planning and policymaking. The IPCC-catalysed Shared Socio-economic Pathways Framework is also being "downscaled" to the Baltic Sea region in terms of descriptors such as land-cover change.

Outreach and Communication

The goal of Baltic Earth outreach is to provide an arena for scientific exchange and discussion, to communicate findings within the Baltic Earth research community and to other researchers, but also to inform stakeholders and society at large. A prime example of co-design is the collaboration with HELCOM, in which a climate change fact sheet is continuously being developed within the joint HELCOM – Baltic Earth Expert Network on Climate Change (EN CLIME) to provide regional climate change information for society (see below).

Another important instrument, apart from the website and social media, is the production of outreach products like newsletters, summary booklets and other outreach publications for non-scientists in English and the languages of the Baltic Sea countries. Presentations and other side-events at stakeholder conferences are used to discuss the current scientific knowledge with non-scientific professionals (practitioners, politicians, corporate representatives), to facilitate the joint development of sustainable solutions.

How to contribute to Baltic Earth

to contribute. Articles are welcome for the Baltic Earth Newsletter; contributions are solicited for other Baltic Earth publications from time to time. Joining a Baltic Earth Working Group is a way to be actively involved in developing and progressing Baltic Earth scientific activities. Interested scientists are invited to approach the respective Working Group chairperson directly (details about the Working Groups are on the Baltic Earth website), or to contact the Baltic Earth Secretariat.

Organisation

Figure 12 Members of Baltic Earth Science Steering Group (BESSG), Baltic Earth Senior Advisory Board (BESAB), and Baltic Earth International Secretariat (IBES) at the 25th semi-annual meeting held on 12 April 2026 in Heringsdorf, Germany. Front row (from left): Katarzyna Koziorowska, Markus Meier, Leonie Barghorn, Heta Rousi, Marc J. Silberberger; middle row (from left): Ralf Weisse, Sirje Keevallik, Georgia Destouni, Piia Post, Agnieszka Jędruch, Kari Hyytiäinen; back row (from left): Matthias Gröger, Kevin Parnell, Tarmo Soomere, Urmas Lips, Jüri Elken, Juris Aigars, Taavi Liblik, Sławomir Sagan, Jan Harff, Karol Kuliński. (Photo: Sonja Ehlers).

Baltic Earth Science Steering Group (BESSG)

Baltic Earth is led and managed by the members of the Baltic Earth Science Steering Group. The group consists of volunteer scientists from research institutions whose activities have strong relevance for Baltic Earth research. As far as possible, scientists from all countries of the drainage basin and from all disciplines relevant to Earth system science participate in the panel. Diversity in terms of career level and gender is also envisaged. The Steering Group is responsible for actively implementing the Science Plan and for providing scientific and strategic leadership to Baltic Earth.

Baltic Earth Science Steering Group members (alphabetically, as of April 2026):

- **Juris Aigars**, Latvian Institute of Aquatic Ecology, Riga, Latvia
- **Leonie Barghorn**, Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany
- **Inga Dailidienė**, Klaipeda University, Department of Geophysical Sciences, Klaipeda, Lithuania
- **Georgia Destouni**, Stockholm University, Department of Physical Geography, Stockholm, Sweden
- **Matthias Gröger**, Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany
- **Kari Hyytiäinen**, Helsinki University, Helsinki Institute of Sustainability Science, Department of Economics and Management, Helsinki, Finland
- **Jamie Jenkins**, Helsinki University, Helsinki Institute of Sustainability Science, Department of Economics and Management, Helsinki, Finland
- **Karol Kuliński (Vice-Chair)**, Institute of Oceanology of the Polish Academy of Sciences, Sopot, Poland
- **Taavi Liblik,** Tallinn University of Technology, Marine Systems Institute, Tallinn, Estonia
- **Urmas Lips**, Tallinn University of Technology, Marine Systems Institute, Tallinn, Estonia
- **Markus Meier (Chair)**, Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany
- **Kai Myrberg**, Finnish Environment Institute, Helsinki, Finland
- **Kevin Parnell**, Tallinn University of Technology, Department of Cybernetics, Tallinn, Estonia
- **Piia Post**, University of Tartu, Institute of Physics, Tartu, Estonia
- **Gregor Rehder**, Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany
- **Heta Rousi,** University of Turku, Department of Biodiversity Sciences, Turku, Finland
- **Marc Silberberger**, National Marine Fisheries Research Institute, Gdynia, Poland
- **Tarmo Soomere**, Tallinn University of Technology, Department of Cybernetics, Tallinn, Estonia
- **Martin Stendel**, Danish Meteorological Institute, National Centre for Climate Research, Copenhagen, Denmark
- **Laura Tuomi**, Finnish Meteorological Institute, Marine Research Unit, Helsinki, Finland
- **Ralf Weisse**, Helmholtz-Zentrum Geesthacht, Institute of Coastal Research, Geesthacht, Germany
- **Tamara Zalewska**, Institute of Meteorology and Water Management – National Research Institute, Gdynia, Poland

Baltic Earth Senior Advisory Board (BESAB)

The Baltic Earth Senior Advisory Board provides advice to the BESSG in terms of strategy and overall directions. Decisions are not taken by the BESAB.

Baltic Earth Senior Advisory Board (alphabetically, as of April 2026):

- **Andris Andrusaitis (Chair)**, BONUS EEIG, Helsinki, Finland (retired)
- **Franz Berger**, Deutscher Wetterdienst, Meteorologisches Observatorium Lindenberg – Richard-Aßmann-Observatorium, Tauche, Germany
- **Jüri Elken**, Tallinn University of Technology, Marine Systems Institute, Tallinn, Estonia
- **Mike Elliott**, University of Hull, Hull, United Kingdom
- **Jan Harff**, University of Szczecin, Institute of Marine and Environmental Sciences, Szczecin, Poland; Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany
- **Petra Kääriä**, HELCOM Secretariat, Helsinki, Finland
- **Sirje Keevallik**, Tallinn University of Technology, Marine Systems Institute, Tallinn, Estonia
- **Anders Omstedt**, University of Gothenburg, Gothenburg, Sweden
- **Anna Rutgersson**, Uppsala University, Department of Earth Sciences, Uppsala, Sweden
- **Sławomir Sagan**, Institute of Oceanology of the Polish Academy of Sciences, Sopot, Poland
- **Oliver Zielinski**, Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany

International Baltic Earth Secretariat

The International Baltic Earth Secretariat (IBES) serves as a focal support point for Baltic Earth and, since 2025, is located at the Leibniz Institute for Baltic Sea Research Warnemünde in Rostock, Germany, and at the Institute of Oceanology of the Polish Academy of Sciences in Sopot, Poland. These two institutes provide the funding for the Secretariat and its activities. Its tasks include supporting the Baltic Earth Science Steering Group, Working Groups, and Panels, as well as preparing and communicating international Baltic Earth meetings, workshops, seminars, conferences, and other activities. Furthermore, the Secretariat coordinates the drafting and finalization of reports (e.g., BEARs, textbooks, meeting reports, proceedings, special issues). The Secretariat also produces the Baltic Earth Secretariat Publication Series (see below) and manages the website and social media accounts.

International Baltic Earth Secretariat (alphabetically, as of November 2025):

- **Sonja Ehlers**, Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany
- **Agnieszka Jędruch**, Institute of Oceanology of the Polish Academy of Sciences, Sopot, Poland
- **Katarzyna Koziorowska**, Institute of Oceanology of the Polish Academy of Sciences, Sopot, Poland

Working Groups

Working Groups are the centres of activity within Baltic Earth. They are established to coordinate dedicated research topics or research that involves several research areas. Of the latter type, a Working Group on Education has been established.

Co-chairs of the Baltic Earth Working Groups (as of April 2026)

- RT1 Climate variability and teleconnections (Florian Börgel, Itzel Ruvalcaba Baroni)
- RT2 Small-scale (sub-mesoscale) processes and their impacts on large-scale Baltic Sea circulation: (Urmas Lips, Evridiki Chrysagi)
- RT3 Natural hazards and their impacts (Matthias Gröger)
- RT4 Sea level and coastal change (Ralf Weisse, Kevin Parnell)
- RT5 Biogeochemistry of the Baltic Sea – Linking observations and modelling (Karol Kulinski, Gregor Rehder)
- RT6 Multiple drivers of Earth system changes (Kari Hyytiäinen, Jamie Jenkins, Susa Niiranen)
- RT7 Marginal Seas – Humans and environment (Jan Harff)
- RT8 Future projections of the Baltic Sea region (Markus Meier, Leonie Barghorn)
- RT9 Philosophical aspects related to Baltic Sea Earth system research (Anders Omstedt)
- Education (Markus Meier)

International scientific cooperation

By definition, Baltic Earth has an international and interdisciplinary but regional focus. Collaboration across national and regional borders and scientific disciplines is crucial to achieve the goal to establish a better understanding of the regional Earth system of the Baltic Sea region for the benefit of the environment and people. Cooperation has been established in BALTEX and Baltic Earth with the following organizations. This list is dynamic and evolving and by no means exhaustive.

GEWEX and WCRP

The Global Energy and Water Cycle Exchanges project (GEWEX, www.gewex.org) of the World Climate Research Programme (WCRP, www.wcrp-climate.org), was the international mother organization of the Baltic Earth predecessor BALTEX which was active from 1993 until 2013. The GEWEX Regional Hydroclimate Projects (RHP) focus on the investigation of the hydrological cycles at the regional scale in order to understand and improve the prediction capabilities of continental to regional hydroclimates. Baltic Earth intends to continue the work of BALTEX and be represented in GEWEX as an RHP.

CORDEX and CLIVAR

Baltic Earth scientists have been active in the WCRP projects Coordinated Regional Climate Downscaling Experiment (CORDEX, www.cordex.org) under the Regional Information for Society (RIfS) project and Climate and Ocean – Variability, Predictability, and Change (CLIVAR, www.clivar.org). While scenario simulations for the atmosphere over the Baltic Sea region are an integral part of CORDEX and are regularly updated, there has not yet been a corresponding project for regional climate ocean projections under the WCRP. As a joint initiative from WCRP CLIVAR – OMDP (Ocean Model Development Panel) and RIfS (Regional Information for Society) – CORDEX, a task force group was therefore set up with the participation of Baltic Earth to close this gap. The mission of the task force is to coordinate regional ocean climate projections (physics, biogeochemistry, sea-ice) worldwide, to advance the science of regional ocean climate modelling and projections, to engage a large community of regional ocean modelers and model users to provide a forum for sharing knowledge and experience across domains, to serve the climate impact and adaptation needs by engaging with relevant users/stakeholders and by providing data and expertise to ocean climate services, to contribute to expert assessment reports.

BSSC

The Baltic Sea Science Congress (BSSC) has drawn a large research community, mostly biologists, oceanographers and geologists, to conferences which are scheduled every second year and are usually hosted by large research institutions that work on the Baltic Sea coasts. Baltic Earth has a close collaboration with BSSC, enlarging the scope to atmospheric research and catchment basin hydrology as well as to regional climate science and modelling.

EGU General Assembly

Baltic Earth has organized or co-organized sessions on “Regional Climate Change and its Impacts in the North and Baltic Sea Regions, Climate and other Drivers of Change: Interlinkages, Ramifications and Impacts in Coastal Regions” or “Coastal Dynamics and Processes under Changing Climate and Human Activities” at the annual European Geosciences Union (EGU) General Assembly.

JPI Oceans and JPI Climate

The Joint Programming Initiatives “Healthy and Productive Seas and Oceans” and “Connecting Climate Knowledge for Europe” are pan-European platforms that “increase the efficiency and impact of research and innovation for sustainably healthy and productive seas and oceans” (JPI Oceans, www.jpi-oceans.eu) or that “jointly coordinate climate research and fund new transnational research initiatives that provide useful climate knowledge and services for post-COP21 Climate Action” (JPI Climate, www.jpi-climate.eu). Baltic Earth contributed to these activities. For instance, scientists from Baltic Earth coordinated a workshop on the Baltic Sea region within the “Knowledge Hub on Sea-Level Rise” to foster the interaction between research and policy on sea level rise.

Cooperation at the science-policy interface

HELCOM

Baltic Marine Environment Protection Commission – Helsinki Commission (HELCOM, www.helcom.fi) is the governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea Area. It was established to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental cooperation with the vision of a healthy Baltic Sea environment in good ecological balance, supporting a wide range of sustainable economic and social activities.

In both 2007 and 2013, HELCOM relied on the BALTEX and Baltic Earth expert network for their Thematic Assessment reports on Climate Change in the Baltic Sea area. In 2019, the Baltic Earth – HELCOM Expert Network on Climate Change (EN CLIME) was formed. EN CLIME serves as a discussion forum to harness the expertise of leading scientists to understand the direct and indirect impacts of climate change on the Baltic Sea environment, to make this expertise accessible to policy makers and to foster a closer dialogue between scientists and policy makers. Hence, EN CLIME acts as HELCOM's advisor on climate change issues and produces the Baltic Sea Climate Change Fact Sheet (first version published in 2021) and its subsequent updates (e.g. in 2024). The knowledge summarised in the fact sheet for policy makers is based on the latest versions of the Baltic Earth Assessment Reports. The fact sheet has been translated into languages other than English in order to achieve a wide distribution in respective countries.

The close collaboration on topics other than climate change between Baltic Earth and HELCOM is envisaged to continue as HELCOM is an important stakeholder at the interface between science and policy in the Baltic Sea region.

Other thematically related international stakeholders are ICES (International Council for the Exploration of the Sea) and OSPAR (Oslo Paris Commission to protect the marine environment of the North-East Atlantic).

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List of acronyms and abbreviations

BACC	BALTEX (BACC I) or Baltic Earth (BACC II) Assessment of Climate Change for the Baltic Sea region
BALTEX	The Baltic Sea Experiment
Baltic Earth	Earth system science for the Baltic Sea region
BEAR	Baltic Earth Assessment Reports
BESAB	Baltic Earth Senior Advisory Board
BESSG	Baltic Earth Science Steering Group
BSSC	Baltic Sea Science Congress
CLIVAR	Climate and Ocean -Variability, Predictability, and Change
CORDEX	Coordinated Regional Climate Downscaling Experiment
EGU	European Geophysical Union
GEWEX	Global Energy and Water Exchanges
GRDC	Global Runoff Data Centre
HELCOM	Helsinki Commission (Baltic Marine Environment Protection Commission)
IBES	International Baltic Earth Secretariat
ICES	International Council for the Exploration of the Seas
ICOS	Integrated Carbon Observation System
JPI Oceans	Joint Programming Initiative “Healthy and Productive Seas and Oceans”
JPI Climate	Joint Programming Initiative “Connecting Climate Knowledge for Europe”
RIfS	Regional Information for Society
OSPAR	Oslo Paris Commission to protect the marine environment of the North-East Atlantic
RHP	Regional Hydroclimate project (of GEWEX)
WCRP	World Climate Research Programme
WDCC	World Data Centre Climate

Writing Team Baltic Earth Science

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International Baltic Earth Secretariat Publications (ISSN 2198-4247)

No. 1 Programme, Abstracts, Participants. Baltic Earth Workshop on ”Natural hazards and extreme events in the Baltic Sea region”. Finnish Meteorological Institute, Dynamicum, Helsinki, 30-31 January 2014. International Baltic Earth Secretariat Publication No. 1, 33 pp, January 2014

No. 2 Conference Proceedings of the 2nd International Conference on Climate Change - The environmental and socio-economic response in the Southern Baltic region. Szczecin, Poland, 12-15 May 2014. International Baltic Earth Secretariat Publication No. 2, 110 pp, May 2014

No. 3 Workshop Proceedings of the 3rd International Lund Regional-Scale Climate Modelling Workshop ”21st Century Challenges in Regional Climate Modelling”. Lund, Sweden, 16-19 June 2014. International Baltic Earth Secretariat Publication No. 3, 391 pp, June 2014

No. 4 Programme, Abstracts, Participants. Baltic Earth - Gulf of Finland Year 2014 Modelling Workshop ”Modelling as a tool to ensure sustainable development of the Gulf of Finland-Baltic Sea ecosystem”. Finnish Environment Institute SYKE, Helsinki, 24-25 November 2014. International Baltic Earth Secretariat Publication No. 4, 27 pp, November 2014

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No. 16 Programme, Abstracts, Participants. Baltic Earth Workshop "Climate projections and uncertainties in the northerb Baltic Sea Region". Helsinki, Finland, 19-20 November 2019, International Baltic Earth Secretariat Publication No. 16, 38 pp, November 2019

No. 17 Anders Omstedt: 45 years of wandering - from processes to systems, through outer and inner seas. An interview by Hans von Storch and Marcus Reckermann with foreword by Jüri Elken, 63 pp. International Baltic Earth Secretariat Publication No. 17, 63 pp, February 2020

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No. 23 Conference Proceedings. 5th Baltic Earth Conference. New Challenges for Baltic Sea Earth System Research, Jūrmala, Latvia 13. May - 17. May 2024. International Baltic Earth Secretariat Publication No.23, 224 pp.

No. 24 Programme, Abstracts, Participants. International Workshop"Multiple Drivers of Earth system changes in the Baltic Sea region", Helsinki, 4 - 5 December 2024 International Baltic Earth Secretariat Publication No. 24, 37 pp

No. 25 Programme, Abstracts, Participants. Special Baltic Earth Colloquium "Achievements, thanks and future challenges", Hamburg, Germany, 4 February 2025, International Baltic Earth Secretariat Publication No. 25, 17 pp

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